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Ant Colony Optimization to Redundancy Allocation for Multi-state Systems

Mustapha Nourelfath and Nabil Nahas
University of Quebec en Abitibi-Témiscamingue (UQAT), UER Sciences Appliquées
445 boulevard de l'Université, Rouyn-Noranda (Québec) J9X 5E4, Canada
e-mail: mustapha.nourelfath@uqat.ca

Abstract

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Many researchers have shown that insect colonies behavior can be seen as a natural model of collective problem solving. The analogy between the way ants look for food and combinatorial optimization problems has given rise to a new computational paradigm, which is called ant colony meta-heuristic. This paper presents an application of ant colony in multi-state reliability optimization problem of a series-parallel system with different redundant elements.

Ants lay down in some quantity an aromatic substance, known as *pheromone*, in their way to food. The pheromone quantity depends on the length of the path and the quality of the discovered food source. An ant chooses a specific path in correlation with the intensity of the pheromone. The pheromone trail evaporates over time if no more pheromone is laid down. Other ants can observe the pheromone trail and are attracted to follow it. Thus, the path will be marked again and will therefore attract more ants. The pheromone trail on paths leading to rich food sources close to the nest will be more frequented and will therefore grow faster. In that way, the best solution has more intensive pheromone and higher probability to be chosen. The described behaviour of real ant colonies can be used to solve combinatorial optimization problems by simulation: artificial ants searching the solution space simulate real ants searching their environment. The objective values correspond to the quality of the food sources. The ant system approach associates pheromone trails to features of the solutions of a combinatorial problem, which can be seen as a kind of adaptive memory of the previous solutions. In order to demonstrate the ant system approach, Dorigo *et al.* (1996) apply it to the classical traveling salesman problem, asymmetric traveling salesman problem, quadratic assignment problem, and job-shop scheduling. Ant system shows very good results in each applied area. The ant system has also been applied with success to other combinatorial optimization problems. The ant system method has not yet been used neither in reliability design of series systems, nor in the redundancy optimization of multi-state systems.

The redundancy optimization problem is also very important in many industrial applications. It is a well known combinatorial optimization problem. In (Levitin *et al.*, 1997), the authors applied a genetic algorithm to solve the problem. This paper uses an ant colony meta-heuristic optimization method. The system and its components have a range of performance levels from perfect functioning to complete failure. Redundant elements are included in order to achieve a desirable level of availability. The elements of the system are characterized by their cost, performance and availability. These elements are chosen from a list of products available on the market. The proposed meta-heuristic determines the minimal cost system configuration under availability constraints. During the optimization process, artificial ants will have to evaluate the availability of a given selected structure of the series-parallel system. To do this, a fast procedure of availability estimation is developed. This procedure is based on a modern mathematical technique: the *z*-transform or universal moment generating function which was introduced in (Ushakov, 1986). It was proven to be very effective for high dimension combinatorial problems: see e.g. (Ushakov *et al.*, 2002), (Levitin and Lisnianski, 2001) and references therein. The developed method allows the availability function of reparable series-parallel MSS to be obtained using a straightforward numerical procedure. Note that the ant colony approach developed and tested in this paper has the advantage to allow elements with different parameters to be allocated in parallel.

References

Dorigo, M., Maniezzo, V., & Colorni, A. (1996). The Ant System: Optimization by a colony of cooperating agents. *IEEE Transactions on Systems, Man and Cybernetics- Part B*, 26(1), 1-13.

Levitin, G., & Lisnianski, A. (2001). A new approach to solving problems of multi-state system reliability optimization. *Quality and Reliability Engineering International*, 47(2), 93-104.

Levitin, G., Lisnianski, A., Ben-Haim, H., & Elmakis, D. (1997). Structure optimization of power system with different redundant elements. *Electric Power Systems Research*, 43(1), 19-27.

Liang, Y. C., & Smith, A. (1999). An Ant System to Redundancy Allocation. *Proceedings of the IEEE Congress on Evolutionary Computation*, 1478-1484.

Ushakov, I., Levitin, G., & Lisnianski, A. (2002). Multi-state system reliability: from theory to practice. *Proc. of 3 Int. Conf. on mathematical methods in reliability, MMR 2002* (pp. 635-638). Trondheim, Norway.

Ushakov, I. (1986). Universal generating function. *Sov. J. Computing System Science*, 24(5), 118-129.